Metal Contact Processing Experiments Towards Realizing 500 °C Durable RF 4H-SiC BJTs

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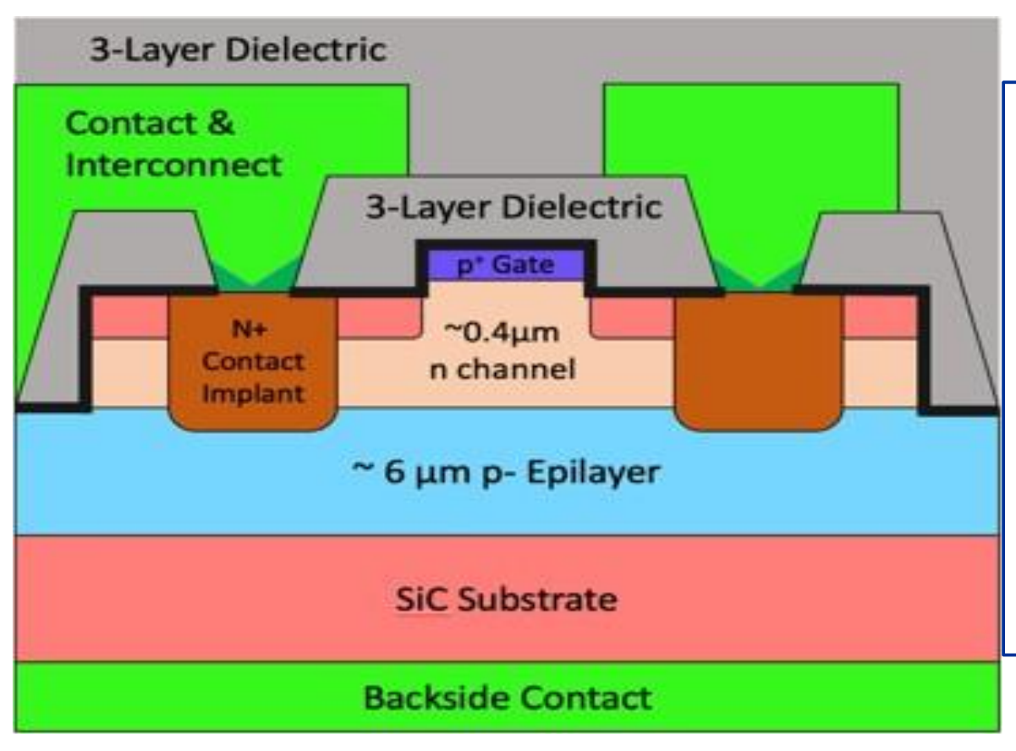
Abstract: This paper presents results from metal contact processing experiments towards the implementation of durable 500 °C high-frequency 4H-SiC **bipolar junction transistors (BJTs**). Specifically, *p*-type ohmic contacts have been demonstrated on a 0.25 µm-thick *p*-type homoepitaxial layer of doping $8 \times 10^{18} \pm 4 \times 10^{18}$ cm^{-3}. Preliminary current-voltage characteristics of fabricated BJTs are presented.

Motivation: Long-lived Venus surface lander needs gathering and **wireless transmission** of surface meteorological data to an orbiter with electronics durable in 460 °C, 9.4 MPa corrosive environment [1].

Background

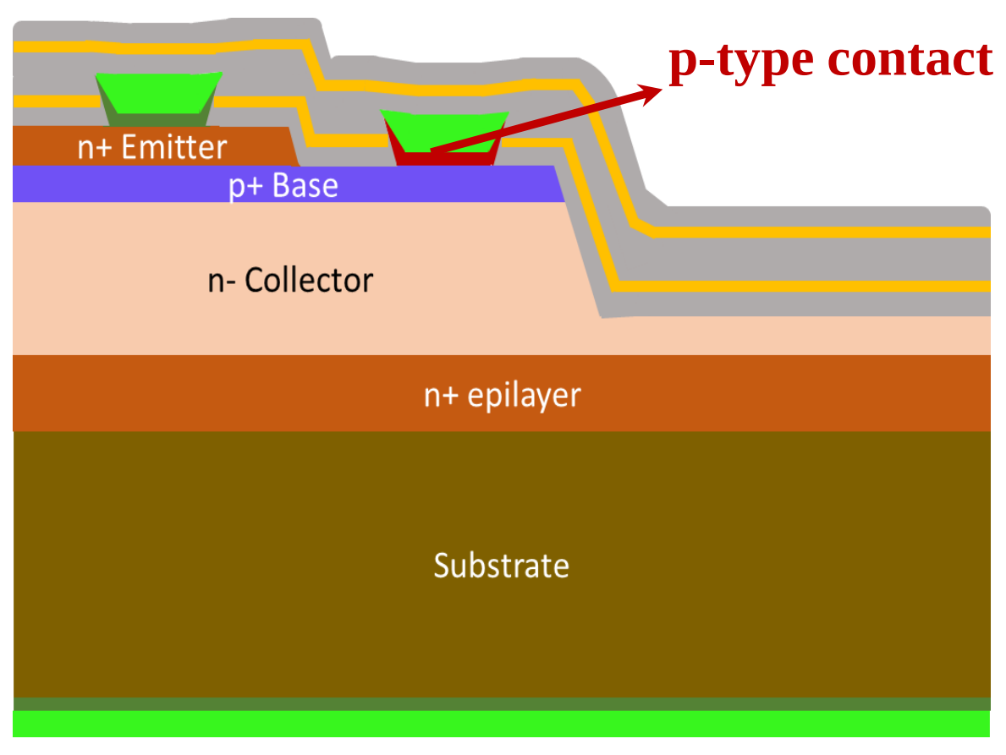
- SiC *npn* BJT development necessary to achieve 100 MHz transmitter circuit **@ 500 °C**
- Leverage technology foundation of NASA Glenn **JFET-based** signal conditioning integrated circuit (IC) chips previously demonstrated in Venus environment chamber 60 days [2]

SiC *n*-channel JFET cross-section



Shared **500 °C durable** technology foundations:
- SiC pn homojunction devices
- Mesa etched device definition
- N-type contacts & interconnect
- Dielectric passivation layers
- Bond pad processing
- Packaging

SiC *npn* BJT cross-section



- Insensitive to *p*-type contact resistance
- 500 °C & Venus durable (proven) [2]
- Low-frequency (< 10 MHz)

- Sensitive to p-type contact resistance
- High-frequency (>100 MHz)
- No ion implantation

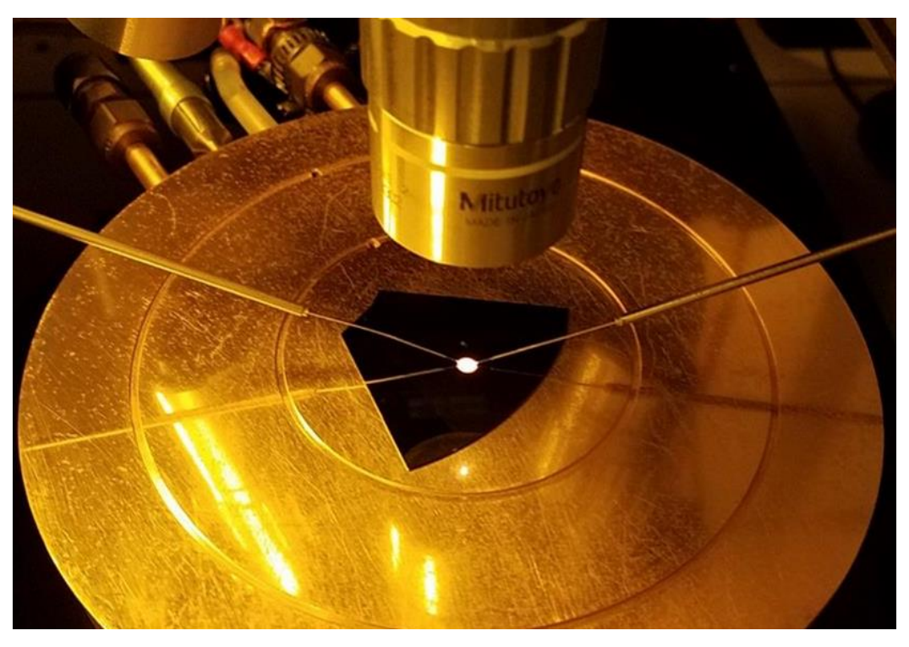
Comparison to prior art of metal contact to p-type layer of BJTs without ion implantation

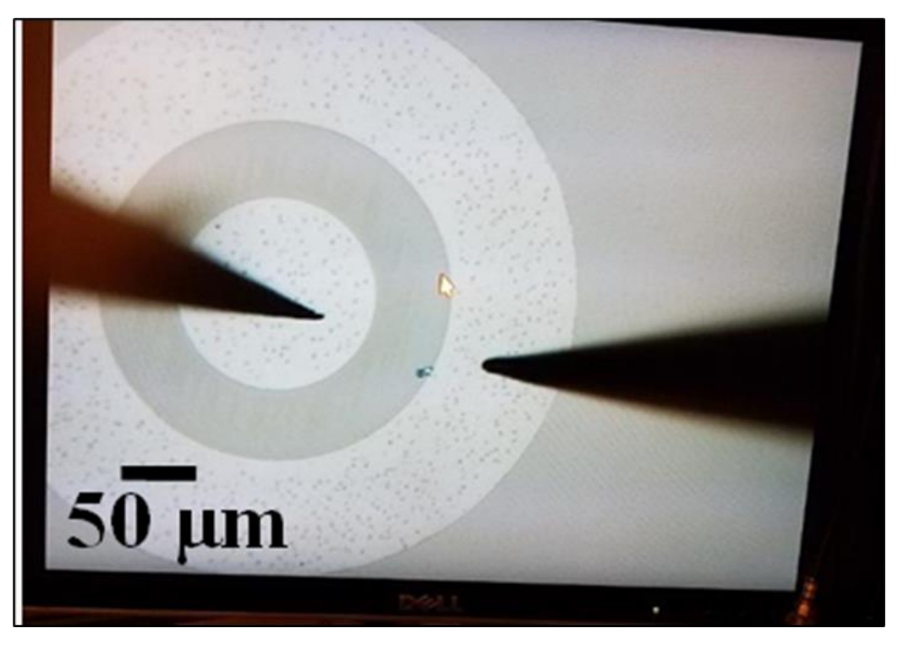
- 0.7 µm-thick p-type layer, doping ~4×10^{17}cm^{-3}, RTA 700 – 800 °C for 2 min. in Ar. [3]
- 0.25 µm-thick p-type layer, doping $8 \times 10^{18} \pm 4 \times 10^{18}$ cm^{-3}, RTA 850 °C for 30 s in vacuum (this work)

Goal of This Work: Durable Ohmic contact to thinner *p*-type base of *npn* BJT without ion implantation

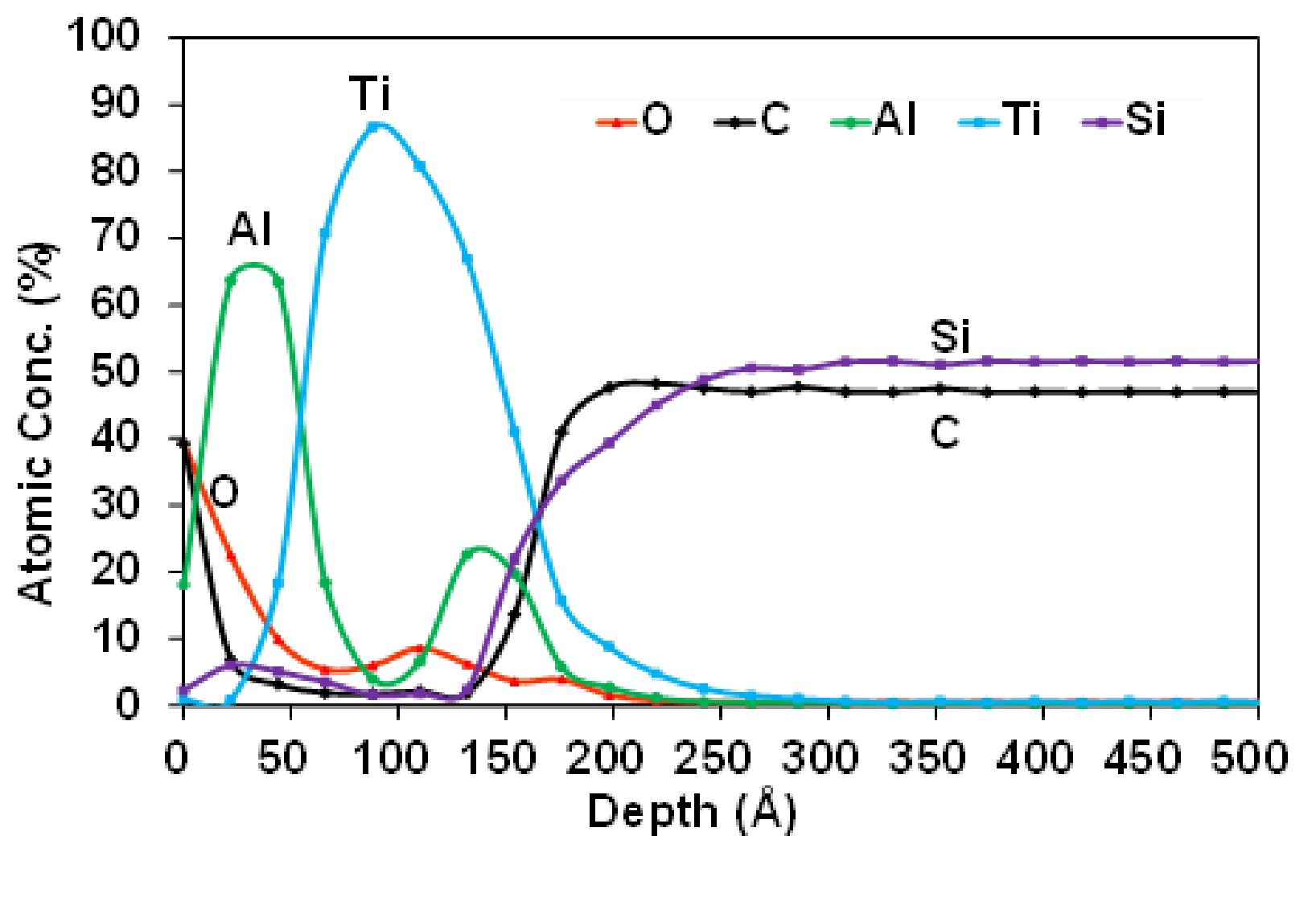
Experiment

- Starting substrate:
  - 100 mm 4H-SiC n-type wafer,
  - 0.5 µm-thick n-type buffer layer, 1×10^{18} cm^{-3},
  - 0.25 µm-thick p-type homoepitaxial layer, doping $8 \times 10^{18} \pm 4 \times 10^{18}$ cm^{-3}
- Same wafer was the source of all the test samples
- Test structure: Circular Transfer Length Method (CTLM) structures
- Metal: Al/Ti/Al [4], 5 nm/10 nm/10 nm by E-beam evaporation
- Experimental investigation: Anneal process
  - Furnace anneals performed at 820 °C, 850 °C, 900 °C and 950 °C for 30 min. in a forming gas atmosphere (2% Hydrogen in Argon)
  - RTA performed at 750 °C, 800 °C, 850 °C, 900 °C and 950 °C for 30 sec. in vacuum
- Analyses: Auger depth profile, I-V sweeps with curve trace

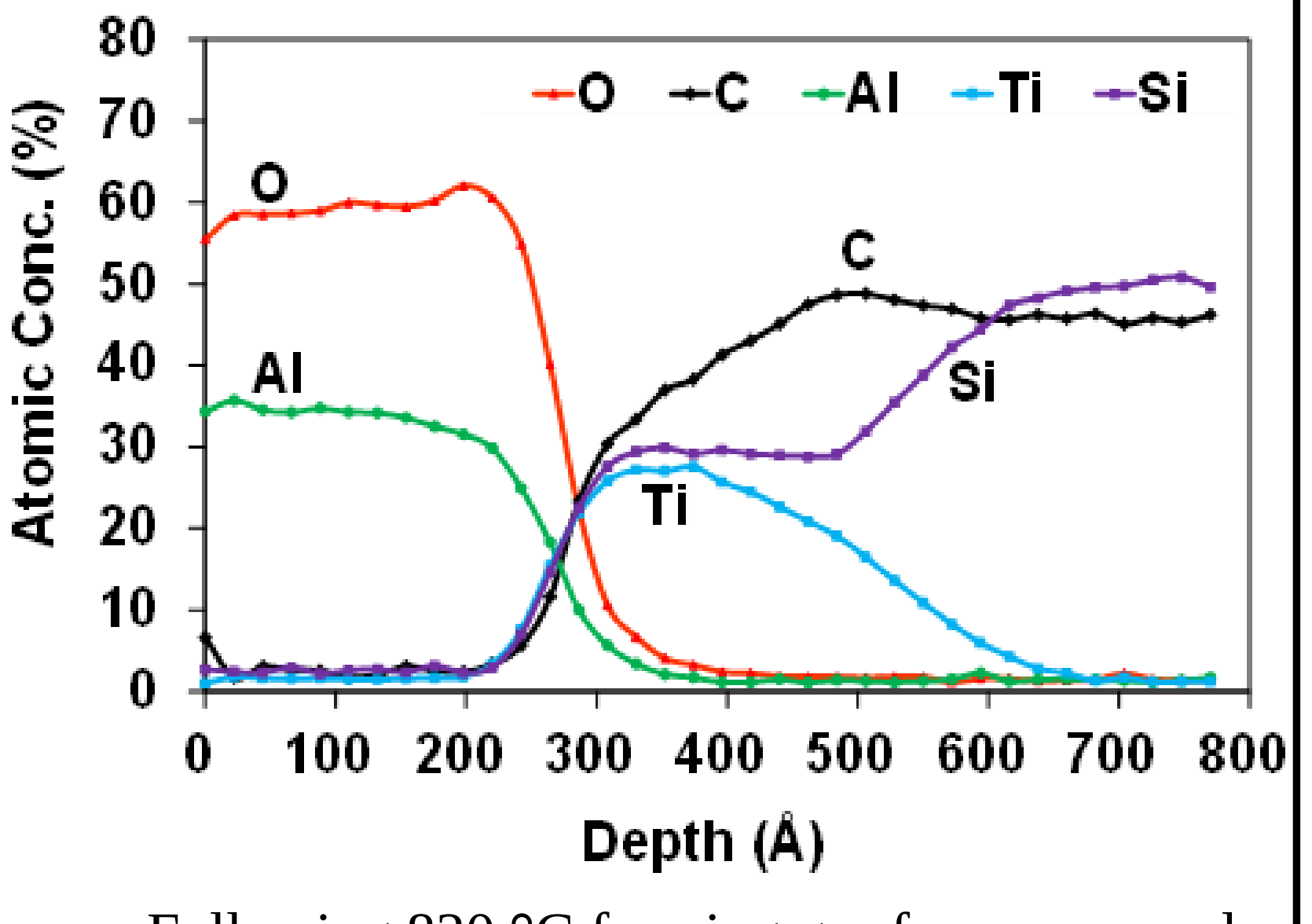




Auger Analyses: Furnace Anneal

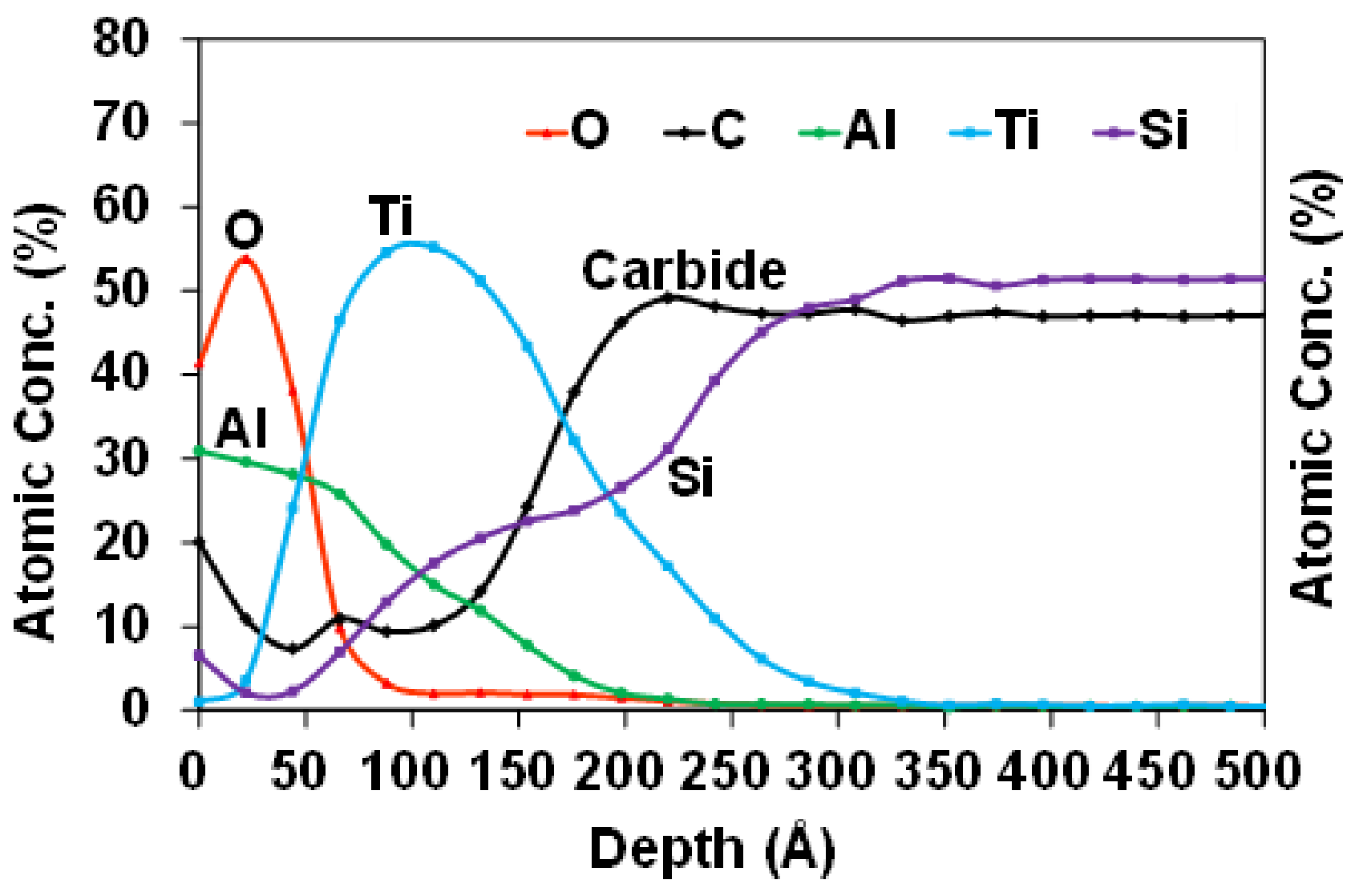


Depth profile of sample with as-deposited Al/Ti/Al

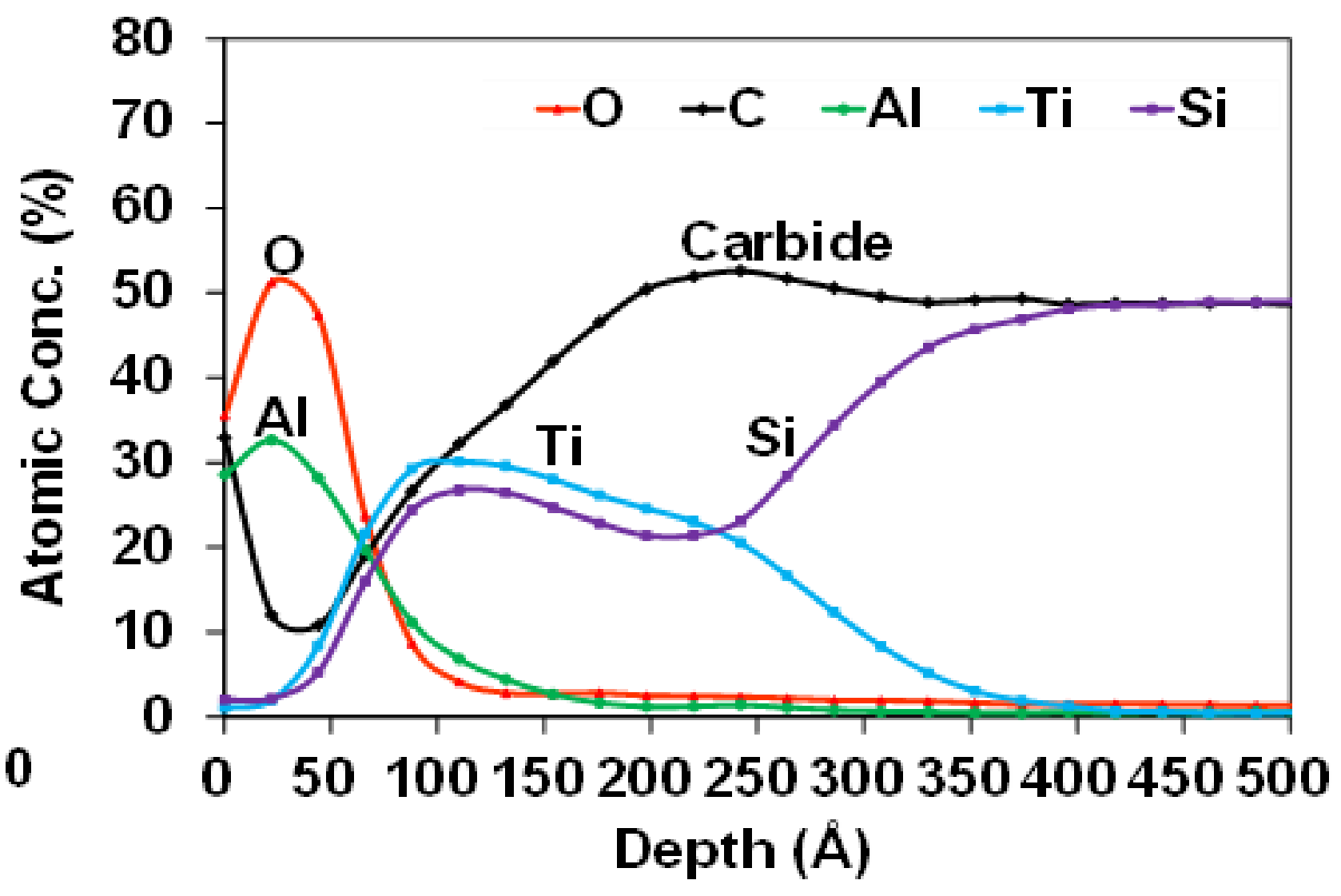


Following 820 °C forming gas furnace anneal

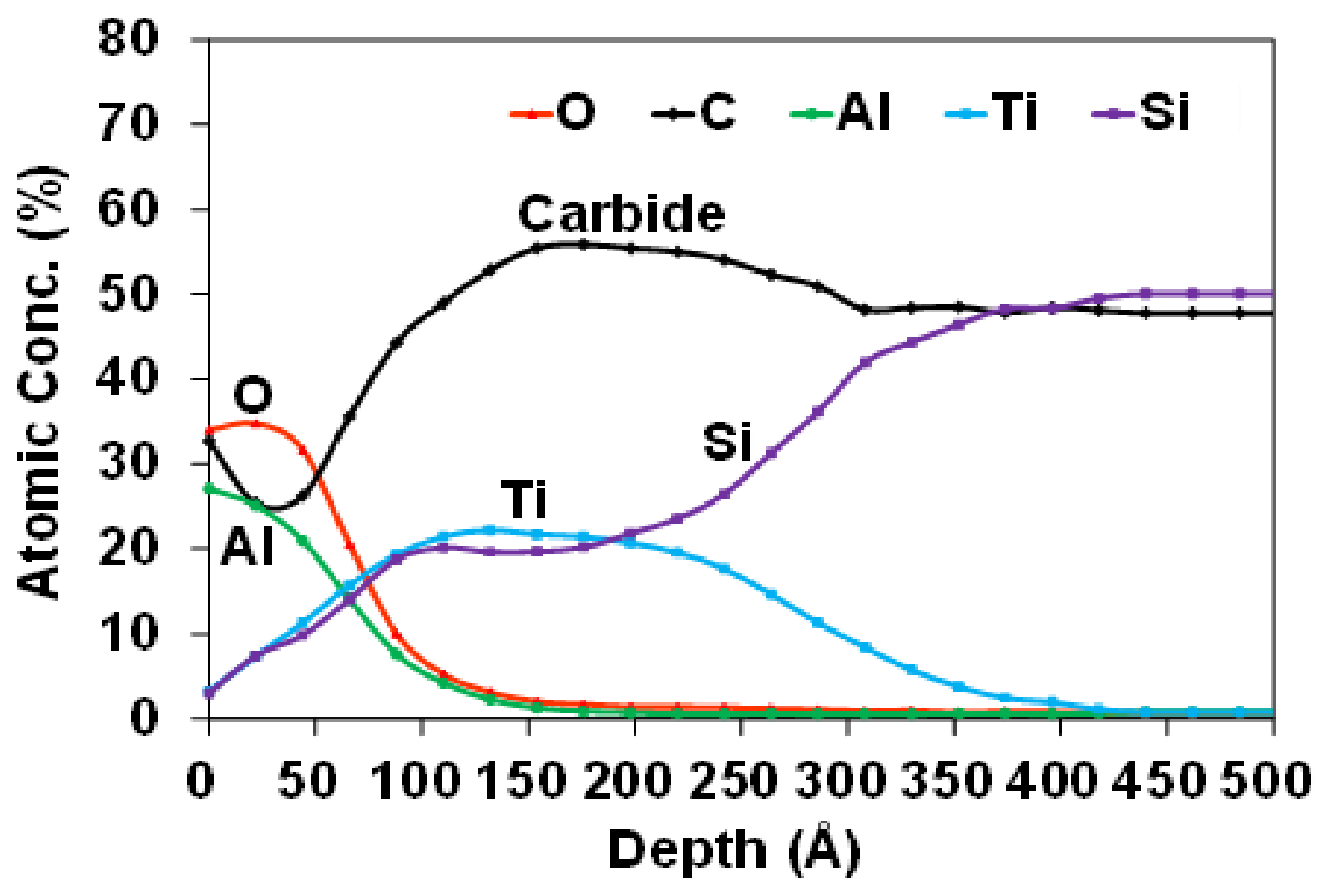
Auger Analyses: RTA Anneal



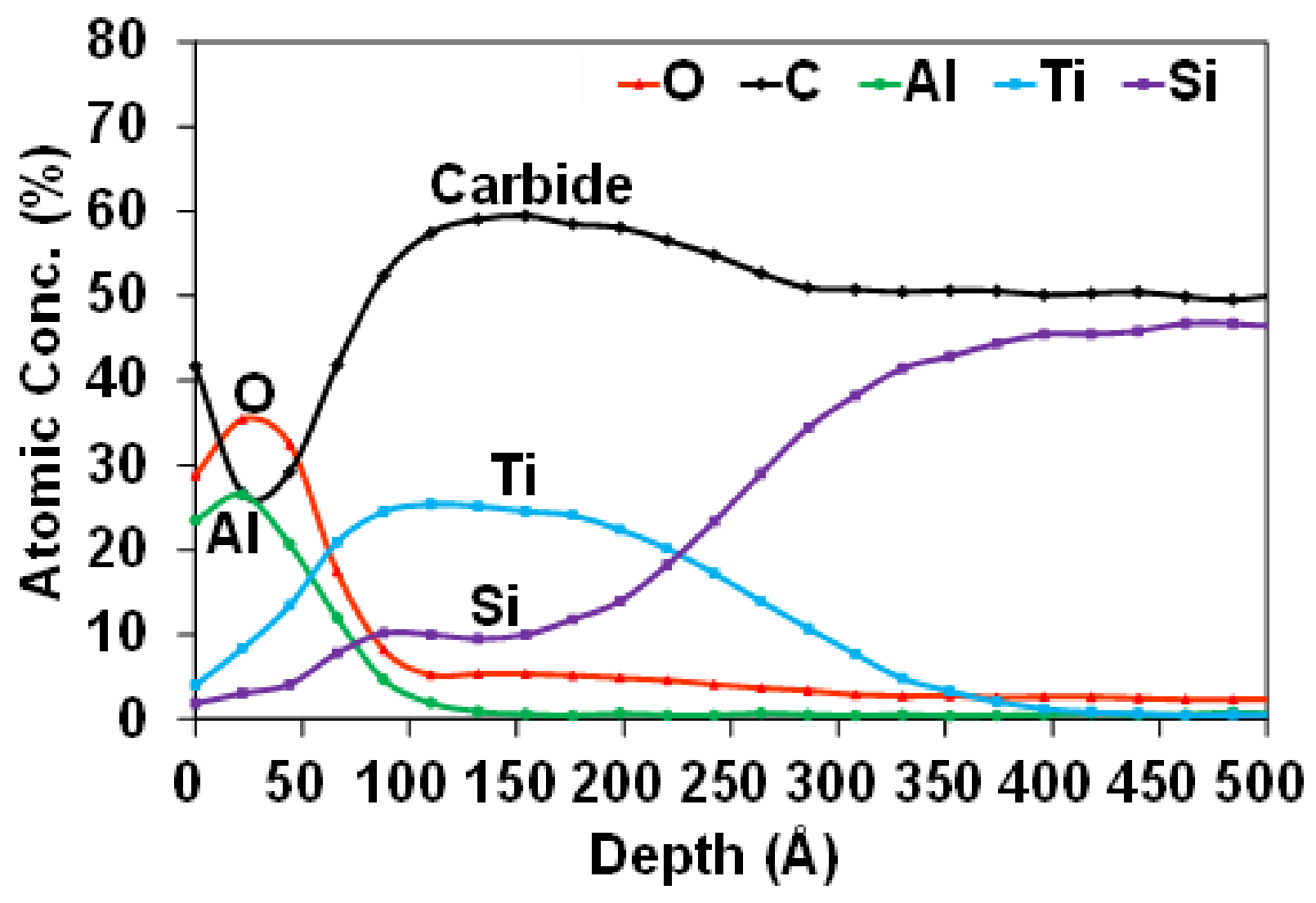
Depth profile following 750 °C RTA anneal



Depth profile following 800 °C RTA anneal

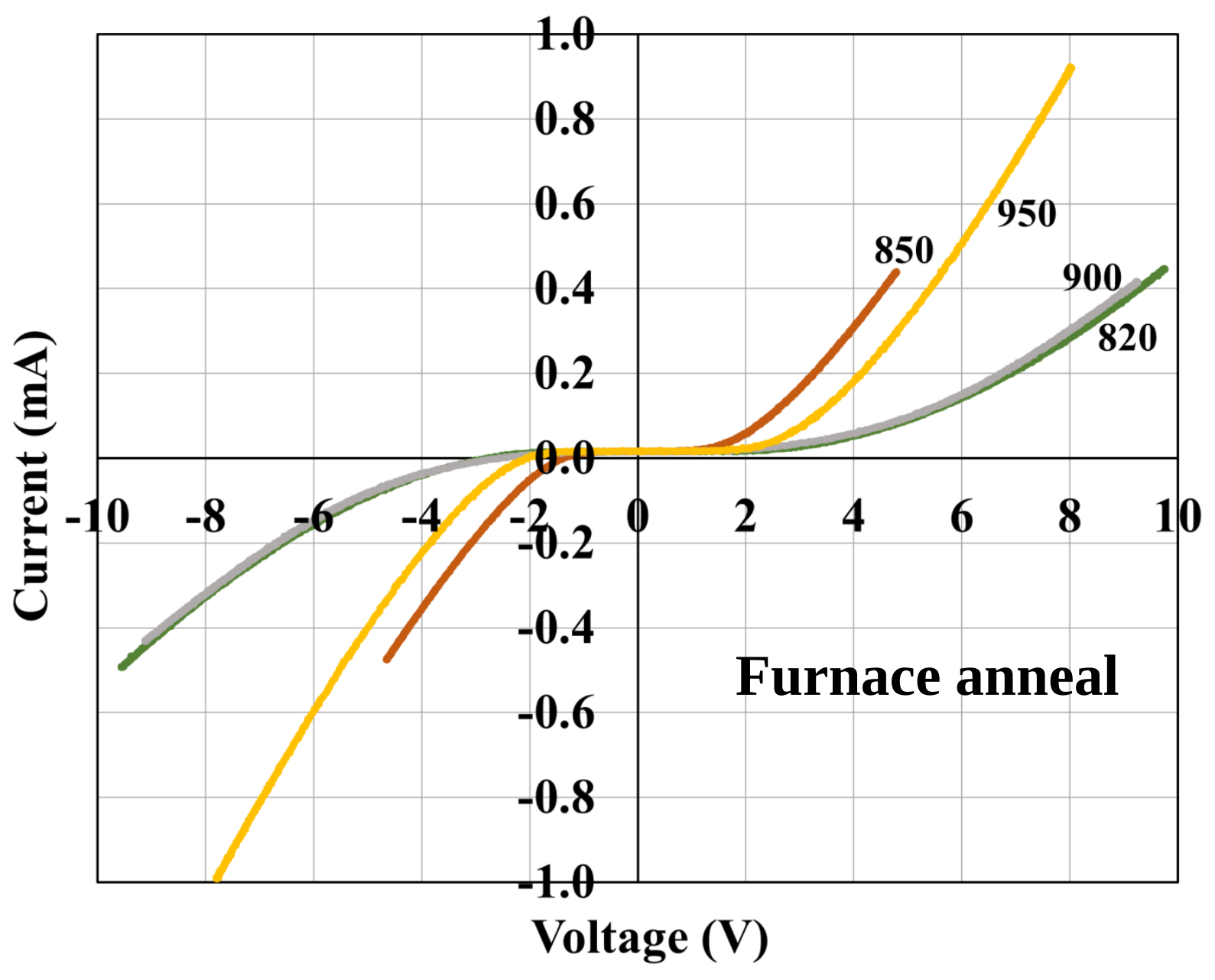


Depth profile following 850 °C RTA anneal

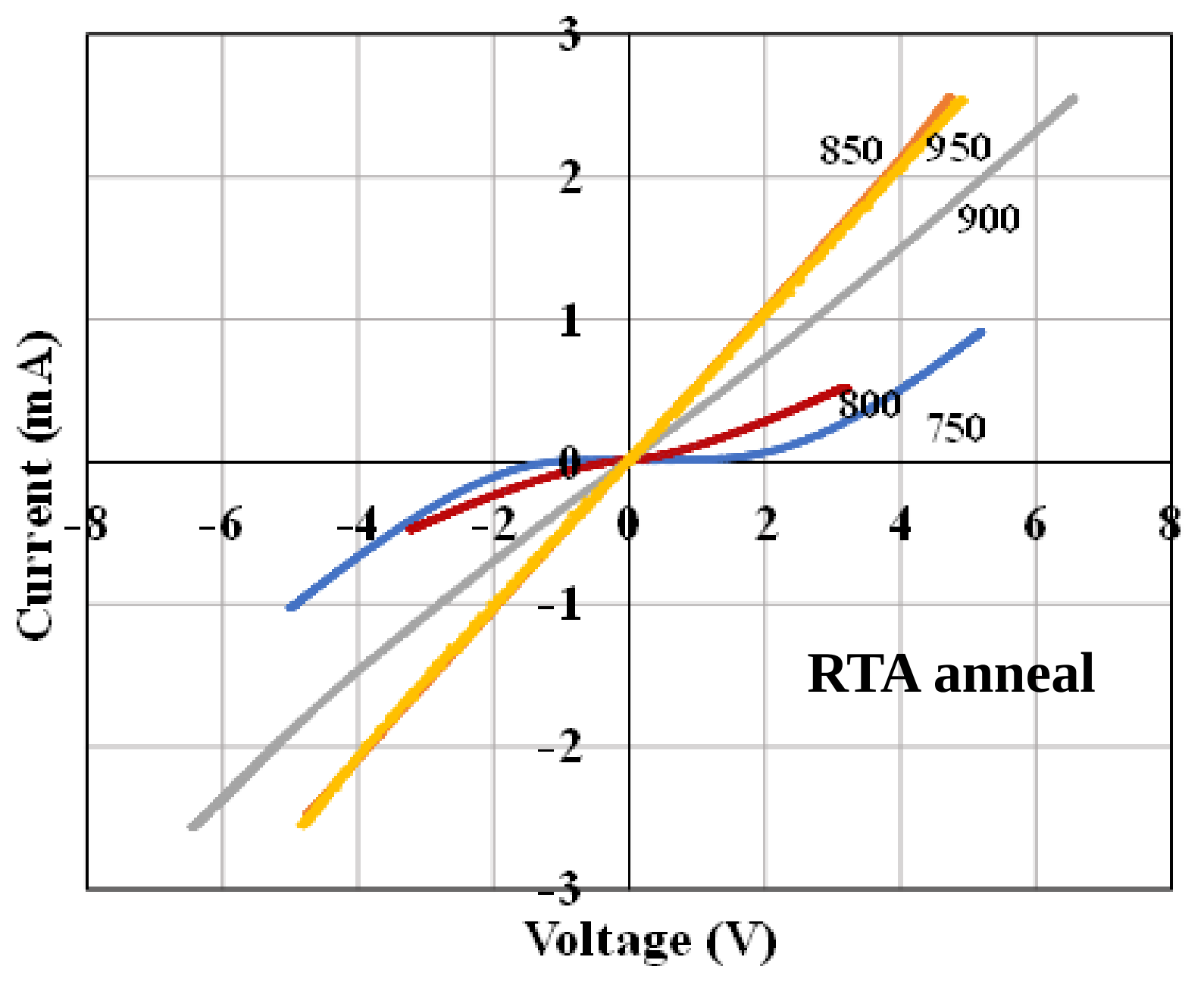


Depth profile following 900 °C RTA anneal

I-V sweeps: Furnace versus RTA anneal

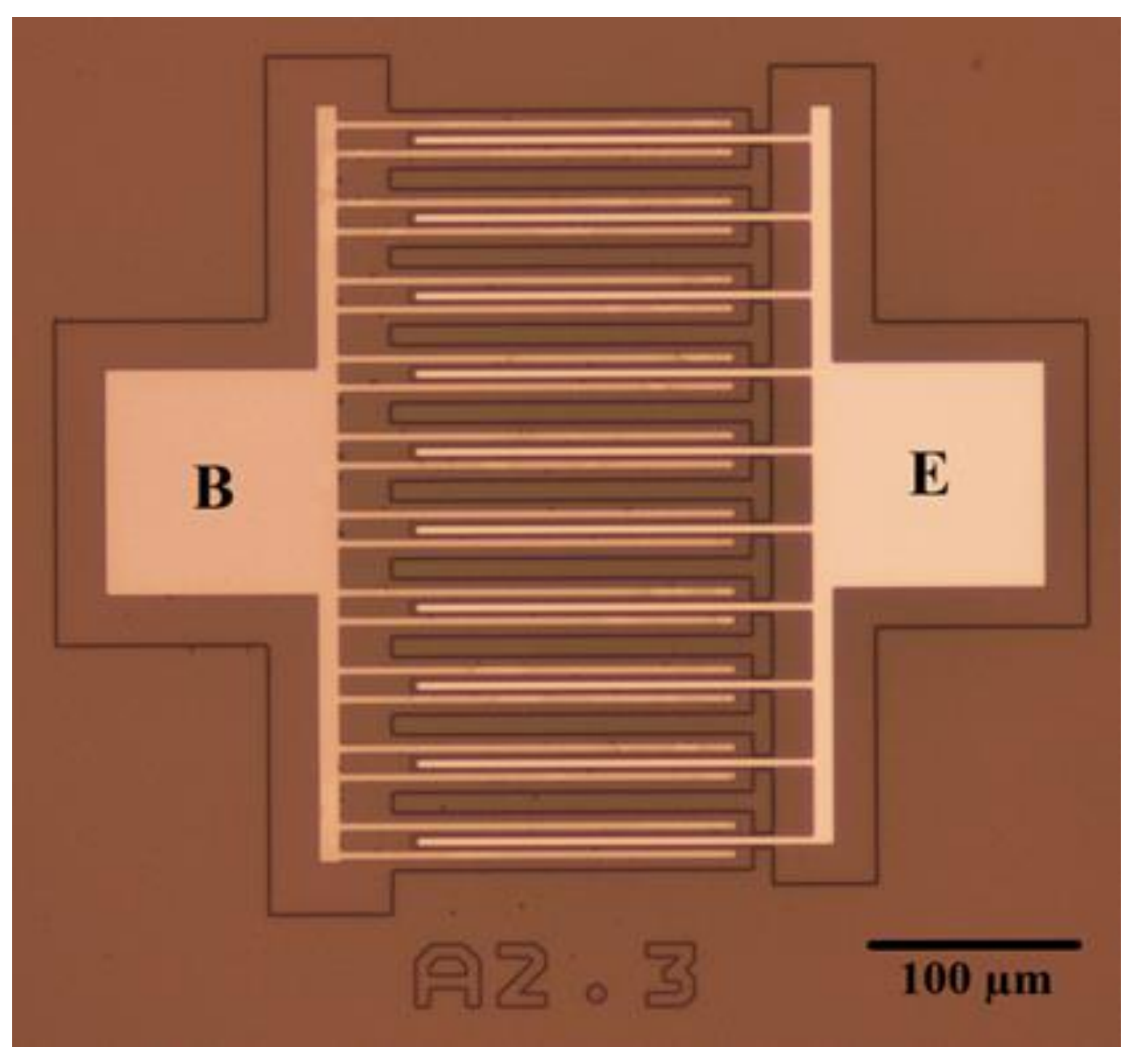


Room temperature *I-V* characteristics after different furnace anneal temperatures in °C.

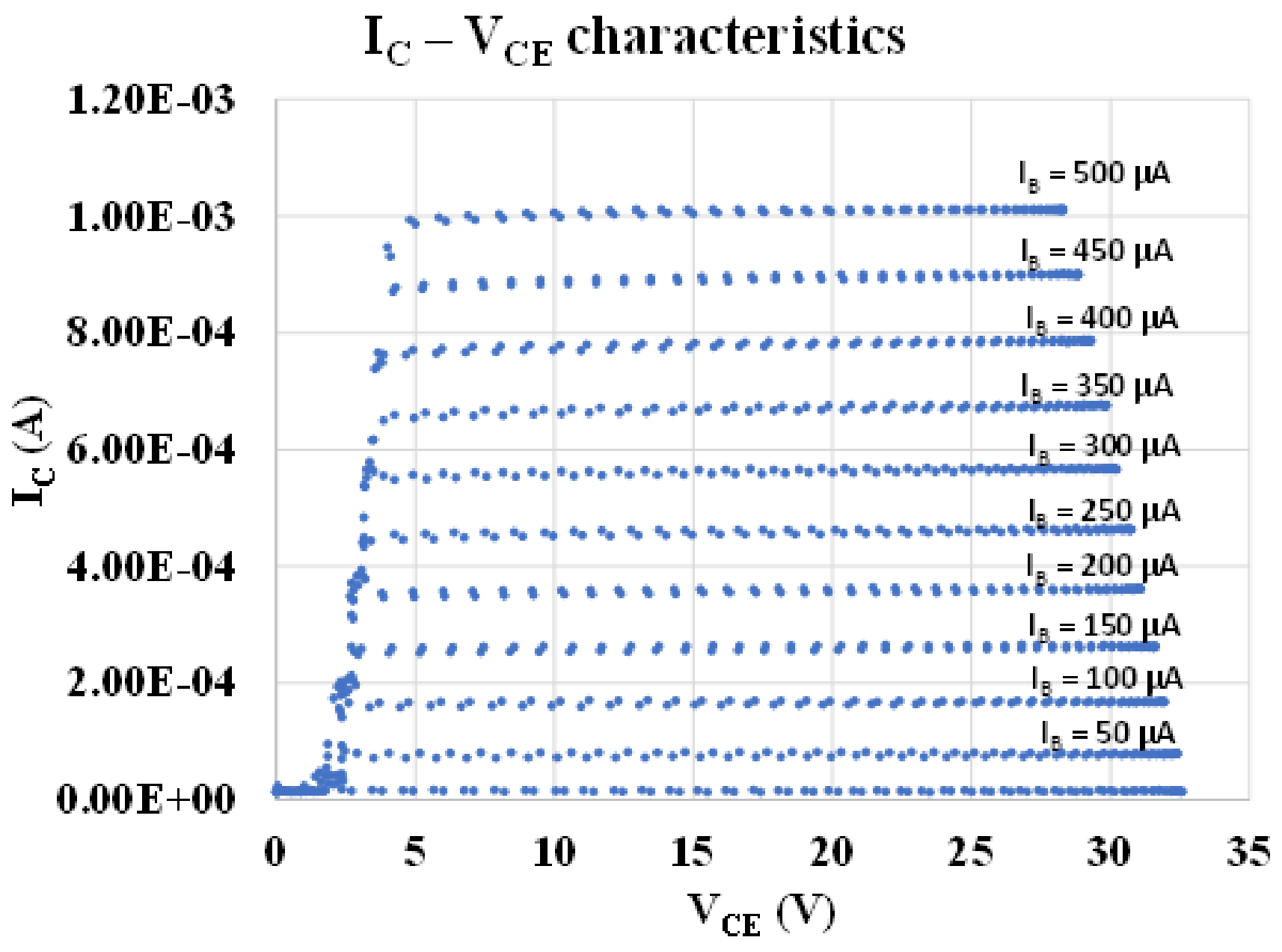


Room temperature *I-V* characteristics after different RTA temperatures in °C.

Preliminary BJT results



Optical micrograph of a partially fabricated BJT; E, emitter; B, base



I-V characteristics of a fabricated BJT at room temperature

- Further processing to complete SiC BJT fabrication by (1) adding thick conductive fingers on top of thin ohmic contact fingers, (2) adding robust wire bonding metal, and (3) annealing n-type contacts is on-going.

Conclusion

- A p-type contact process, without the use of ion implantation to reduce contact resistance, towards the realization of a Venus-durable BJT was successfully developed. The Auger analysis shows that the titanium is fully reacted with the carbon and silicon forming the preferred $Ti_xSi_yC_z$ compound [4].
- Preliminary room-temperature *I-V* measurements of partially fabricated BJTs show promise.
- Future tests will include RF performance validation (gain and frequency response) versus temperature and long-duration demonstration in Venus surface environmental conditions.

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